|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Grade** | **Big Idea** | **Essential Questions** | **Concepts** | **Competencies** | **Vocabulary** | **Standard** | **Eligible Content** |
| **PreK-2** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Different kinds of matter exist in various states. | Observe, describe, and classify matter by properties and uses (e.g., size, shape, weight, solid, liquid, gas). | Matter  Weight  Liquid  Gas  Solid  Classify  Describe | 3.2.3.A1  3.2.4.A1  3.2.3.A2 | S4.C.1.1.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Matter can be described and classified by its observable properties. | Observe, describe, and classify matter by properties and uses (e.g., size, shape, weight, solid, liquid, gas). | Matter  Weight  Liquid  Gas  Solid  Properties | 3.2.3.A1  3.2.4.A1  3.2.3.A2 | S4.C.1.1.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Different kinds of matter exist in various states. | Plan and carry out investigations to test the idea that warming some materials causes them to change from solid to liquid and cooling causes them to change from liquid to solid. | Solid  Liquid  Investigations | 3.2.1.A.1 | S4.C.1.1.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Matter can be described and classified by its observable properties. | Plan and carry out investigations to test the idea that warming some materials causes them to change from solid to liquid and cooling causes them to change from liquid to solid. | Solid  Liquid | 3.2.1.A.3  3.2.1.A.4 | S4.1.1.2  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Different kinds of matter exist in various states. | Distinguish between opinions and evidence in determining whether objects in a given set occur naturally or are manufactured. | Natural  Human made  Manufactured | 3.2.1.A1 | S4.C.1.1.2  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Matter can be described and classified by its observable properties. | Distinguish between opinions and evidence in determining whether objects in a given set occur naturally or are manufactured. | Natural  Human made | 3.2.1.A1 | S4.A.1.3.  S4.C.1.1.2  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Heating or cooling a substance may cause changes that can be observed.  Sometimes these changes are reversible, and sometimes they are not. | Provide evidence that some changes caused by heating or cooling can be reversed and some cannot. | Melting  Boiling  Freezing | 3.2.2.A1 3.2.2.A3 | S4.C.1.1.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Different properties are suited to different purposes. | Analyze data from testing objects made from different materials to determine if a proposed object functions as intended. | Data  Test | 3.2.2.A1 | S4.C.1.1.2  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | A great variety of objects can be built up from a small set of pieces. | Design an object built from a small set of pieces to solve a problem and compare solutions designed by peers given the same set of pieces. | Problem Solving | 3.2.2.A4  3.2.2.A6 | S4.A.3.2.B  S4.A.3.2  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Objects or samples of a substance can be weighed, and their size can be described and measured. | Analyze data from tests of a student-designed tool to determine if the tool measures weight or size accurately, and compare to standard measuring tools. | Weight  Measure | 3.2.2.A6 | S4.C.1.1.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
|  |  |  |  |  |  |  |  |
| **3-4** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Mass is conserved when it goes through a physical change. | Design an investigation to demonstrate the conservation of mass during physical changes (e.g., freezing and warming). | Conservation  Mass  Freeze  Properties  Change | 3.2.4.A3  3.2.4.A5  3.2.3.A4  3.2.3.A3  3.2.3.A5 | S4.C.1.1.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Mass is conserved when it goes through a physical change. | Design an investigation to determine the relationships among the energy transferred, the type of matter, the amount of sample, and the resulting change in temperature of the sample. | Conservation  Mass  Freeze  Properties  Change | 3.2.4.A3  3.2.4.A5  3.2.3.A4  3.2.3.A3  3.2.3.A5 | S4.C.1.1.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
|  |  |  |  |  |  |  |  |
| **5-6** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | When two or more different substances are mixed, a new substance with different properties may be formed. | Generate and compare multiple solutions that meet the desired criteria of improving a property or a material within the constraints of changing the type of substances, the amount of substances used to make the material, and the temperature at which they are mixed. | Chemical Change vs. Physical Change  Mass  Volume  Temperature | 3.2.3.A4, 3.2.4.A4 | S8.C.1.1.3  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **5-6** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. | Argue from evidence to support the theory that matter is made of particles too small to be seen. | Matter  Particles | 3.2.7.A2 | S8.C.1.1.2  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **5-6** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Measurements of a variety of properties can be used to identify materials. | Make observations and measurements to identify given materials based on their properties. | Properties like:  Mass  Volume  Hardness  Moh’s Scale  Streak Tests  Porosity  Solubility | 3.2.6.A5 3.2.6.A1 | S8.C.1.1.2  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **5-6** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | The amount of matter is conserved when it changes form. | Use simple models to describe that regardless of what reaction or change in properties occur, the total mass of the substances involved does not change. | Conservation of Mass | 3.2.6.A3 | S8.C.1.1.3  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **5-6** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | When two or more different substances are mixed, a new substance with different properties may be formed; such occurrences depend on the substances and the temperature. | Investigate the interaction of two or more substances to provide evidence that when different substances are mixed, one or more new substances with different properties may or may not be formed. | Mixtures vs. Compounds  Chemical Change | 3.2.6.A4 3.2.7.A4 | S8.C.1.1.1  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **5-6** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | No matter what reaction or change in properties occurs, the total mass of the substances does not change. | Investigate and determine the effect on the total mass of matter when substances interact to form new substances. | Chemical Change | 3.2.6.A3 | S8.C.1.1.3  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **5-6** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | No matter what reaction or change in properties occurs, the total mass of the substances does not change. | Plan and carry out investigations to determine the effect on the total mass of a substance when the substance changes shape, phase, and/or is dissolved. | Physical Changes  Dissolve | 3.2.6.A3 | S8.C.1.1.3  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | All substances are made of atoms, which combine with one another in various ways.  Atoms form molecules that range in size and solids may be formed from molecules or extended structures with repeating subunits (e.g., crystals). | Construct and use molecular-level models to explain that atoms combine to form new substances, comparing those with simple molecules to those with extended structures. | Atoms  Nucleus  Electrons  Protons  Neutrons  Molecules  Compounds | S8.C.1.1 3.4.7.A 3.2.6.A5 | S8.C.1.1.1  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Pure substances are made from a single type of atom or molecule; each pure substance has characteristic physical and chemical properties that can be used to identify it. | Plan investigations to generate evidence supporting the claim that one pure substance can be distinguished from another based on characteristic properties. | Pure Substance  Characteristic Properties  Density  Boiling point  Melting point  Malleability  Conductivity  Flammability  Reactivity | 3.2.6.A2 3.2.6.A4 3.2.7.A1 | S8.C.1.1.2  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. | Use a simulation or mechanical model to determine the effect on the temperature and motion of atoms and molecules of different substances when thermal energy is added or removed from the substance. | Solid  Liquid  Gas  Molecular Motion  Thermal energy  Temperature  States of matter | 3.2.5.A1 3.2.6.A1 3.2.6.A5 | S8.C.1.1.2  S8.C.3.1.2  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. | Use a simulation or mechanical model to determine the effect on the temperature and motion of atoms and molecules of different substances when thermal energy is added or removed from the substance. | Temperature  Pressure  Change of State | 3.2.5.A1 3.2.6.A1 3.2.6.A5 | S8.C.3.1.2  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. | Develop representations of reactants and products showing how atoms regroup during chemical reactions to account for the conservation of mass. | Reactants  Products | S8.C.1.1 3.4.7.A 3.2.6.A4 3.2.7.A4 | S8.C.1.1.3  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | The total number of each type of atom is conserved, and thus the mass does not change. | Develop representations of reactants and products showing how atoms regroup during chemical reactions to account for the conservation of mass. | Conservation of Mass | S8.C.1.1 3.4.7.A 3.2.6.A4 3.2.7.A4 | S8.C.1.1.3  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. | Analyze and generate explanations from the comparison of the physical and chemical properties of reacting substances to the properties of new substances produced through chemical reactions. | Chemical Properties  Physical Properties | S8.C.1.1 3.4.7.A 3.2.6.A4 3.2.7.A4 | S8.C.1.1.1  S8.C.1.1.2  S8.C.1.1.3  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Some chemical reactions release energy, others store energy. | Design, construct, and test a device that either releases or absorbs thermal energy by chemical processes. | Exothermic  Endothermic | 3.2.6.A3 3.2.7.A3 | S8.C.1.1.3  S8.C.3.1.3  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
|  |  |  |  |  |  |  |  |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Stable forms of matter are those in which the electric and magnetic field energy is minimized. | Construct models showing that stable forms of matter are those with minimum magnetic and electrical field energy. | Lewis Dot Structures | S11.C.1.1 3.4.10.A 3.2.C.A1 |  |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. | Construct various types of models showing that energy is needed to take molecules apart and that energy is released when the atoms come together to form new molecules. | Binding Energy | S11.C.1.1 3.4.10.A 3.2.C.A1 |  |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. | Develop explanations to support predictions about how the patterns of electrons in the outer level of atoms, as represented in the periodic table, reflect and can predict properties of elements. | Subatomic Particles  Nucleus  Protons  Neutrons  Electrons  Elements  Electron Affinity  Ionization Energy  Chemical Reactivity  Electronegativity  Atomic Radius | 3.2.10.A1 3.2.C.A1 | CHEM.A.2.3  CHEM.A.2.1 |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. | Develop representations showing the patterns and behavior of electrons as determined by the quantized energy levels of atoms. | Electronic Configuration  Emission Spectra  Ground State  Orbitals  Quantized Energy Levels | 3.2.10.A1 3.2.C.A1 | CHEM.A.2.2 |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | The solubility of solutions depends on their properties and other factors. e.g., dissolving, dissociating | Develop explanations and mathematical expressions comparing solutions made from ionic and covalent solutes and how various factors affect the solubility of these solutions | Homogeneous  Heterogeneous  Molarity  Percent by Mass  Percent by Volume  Solubility | 3.2.C.A1 | CHEM.A.1.2 |
| **9 -12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | The mole, as a fundamental unit, is used to represent atomic particles. | Analyze and interpret data sets,using the mole concept, to mathematically determine amounts of representative particles. | Mole  Stoichiometric Relationships | 3.2.C.A4 | CHEM. B.1.1 |
| **9 -12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | The mole, as a fundamental unit, is used to represent the composition of matter. | Analyze and interpret provided data to apply the law of definite proportions, to determine empirical and molecular formulas of compounds, percent composition and mass of elements in a compound. | Empirical Formulas  Molecular Formula | 3.2.C.A2 | CHEM. B.1.2 |
| **9 -12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | The kinetic molecular theory is used to explain the behavior of gases | Utilize mathematical relationships to predict changes in the number of particles, the temperature, the pressure, and the volume in a gaseous system (i.e., Boyle’s Law, Charles’ Law, Dalton’s Law of partial pressures, the combined gas law, and the ideal gas law). | Boyle’s Law  Charles’s Law  Dalton’s Law of Partial Pressures  Combined Gas Law  Ideal Gas Law | 3.4.10.A |  |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. | Construct arguments for which type of atomic and molecular representation best explains a given property of matter. Types of atomic and molecular representations can include computer-based, simulations, physical, ball and stick, and/or symbolic. | Atoms  Molecules  Ions | 3.2.C.A1 3.2.10.A1 | CHEM.B.1.4 |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. | Analyze and interpret data obtained from measuring the bulk properties of various substances to explain the relative strength of the interactions among particles in the substance. | Vapor Pressure  Surface Tension  Melting Point  Boiling Point | 3.2.C.A2 | CHEM.B.1.3  CHEM.A.2.3 |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in total binding energy (i.e., the sum of all bond energies in the set of molecules) that are matched by changes in kinetic energy. | Analyze and interpret data to support claims that energy of molecular collisions and the concentration of the reacting particles affect the rate at which a reaction occurs, limited to simple reactions. | Limiting Reactants  Excessive Reactants | S11.C.1.1 3.4.10.A | CHEM.B.2.1 |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. | Develop and use models to explain that atoms (and therefore mass) are conserved during a chemical reaction. Models can include computer models, ball and stick models, and drawings. | Reactants  Products  Synthesis  Decomposition  Single Displacement  Double Replacement  Combustion | 3.2.10.A2 3.2.C.A2 3.2.10.A4 3.2.C.A4 | CHEM.B.2.1.5 |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. | Refine designs in chemical systems to support changes in reaction conditions which can be used to optimize the output of a chemical process, limited to simple reactions. | Equilibrium | 3.2.10.A4 | CHEM.B.2.1 |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangement of atoms into new molecules, with consequent changes in total binding energy (i.e., the sum of all bond energies in the set of molecules) that are matched by changes in kinetic energy. | Construct mathematical models to explain how energy changes in chemical reactions are caused by changes in binding energy as the reactants form products and in which changes in the kinetic energy of the system can be detected as change in temperature. | Chemical Processes  Bond Energy  Reaction Rates | 3.2.10.A3 |  |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. | Construct and communicate explanations using the structure of atoms, trends in the periodic table and knowledge of the patterns of chemical properties to predict the outcome of simple chemical reactions. | Atoms  Chemical Properties  Elements | 3.2.10.A1 3.2.C.A4 | CHEM.B.2.1 |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Chemical processes and properties of materials underlie many important biological and geophysical phenomena. | Construct and communicate explanations that show how chemical processes and/or properties of materials are central to biological and geophysical systems. | Chemical Processes  Geophysical Phenomena  Chemical Properties | 3.2.10.A3 |  |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. | Use system models (computers or drawings) to construct molecular-level explanations to predict the behavior of systems where a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. | Reverse Reaction  Reaction | 3.2.10.A4 3.2.C.A4 3.2.12.A5 | CHEM.B.2.1 |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve changes in nuclear binding energies. The total number of neutrons plus protons does not change in any nuclear process. Strong and weak nuclear interactions determine nuclear stability and processes. | Construct models to explain changes in nuclear energies during the processes of fission, fusion, and radioactive decay and the nuclear interactions that determine nuclear stability. | Nuclear Fission  Nuclear Fusion  Strong Nuclear Force  Weak Nuclear Force  Stable Nuclei  Unstable Nuclei | 3.2.12.A2 |  |
| **9-12** | Matter can be understood in terms of the types of atoms present and the interactions both between and within atoms. | How can one explain the structure, properties, and interactions of matter? | Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the maximum ages of rocks and other materials from the isotope ratios present. | Analyze and interpret data sets to determine the maximum age of samples (rocks, organic material) using the mathematical model of radioactive decay. | Radioactive  Decay  Alpha Radiation  Beta Radiation  Gamma Radiation  Half-Life | 3.2.12.A2 |  |
|  |  |  |  |  |  |  |  |
| **PreK-2** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Objects pull or push each other when they collide or are connected and can have different strengths and directions. Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. | Investigate and construct explanations about the effect of pushes and pulls in different directions and of different strengths on the resulting motion of objects. | Speed  Explanation  Motion | 3.2.3.B1 3.2.4.B1 | S4.A.1.1  S4.C.3.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Objects pull or push each other when they collide or are connected and can have different strengths and directions. Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. | Construct an explanation for why an object subjected to multiple pushes and pulls might stay in one place or move. | Speed | 3.2.3.B1 3.2.4.B1 | S4.C.3.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Objects pull or push each other when they collide or are connected and can have different strengths and directions. Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. | Carry out an investigation to show how there is a change in motion and/or shape when objects touch or collide and is related to the speed of the objects. | Speed  Investigation | 3.2.3.B1 3.2.4.B1 | S4.C.3.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | An object sliding on a surface or sitting on a slope experiences a pull due to friction on the object due to the surface that opposes the object’s motion. | Analyze data to determine the relationship between friction and the warming of objects and share a design solution to reduce friction between two objects. | Friction  Data  Solution | 3.2.3.B1  3.2.4.B1 | S4.C.3.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
|  |  |  |  |  |  |  |  |
| **3-4** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object’s speed or direction of motion. | Investigate the motion of objects to determine observable and measurable patterns to predict future motions (e.g., falling objects and Earth, Moon, Sun). | Force  Net Force  Predict  Pattern | 3.2.3.B1  3.2.4.B1 | S4.C.3.1 |
| **3-4** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object’s speed or direction of motion. | Investigate the variables that may affect how objects fall. | Force  Net Force  Speed | 3.2.3.B1  3.2.3.B2  3.2.4.B1  3.2.4.B2  3.2.3.B6 | S4.C.3.1 |
| **3-4** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | When objects touch or collide, they push on one another and can change motion or shape. Magnets create a magnetic field that can exert an attracting or repelling force on other objects that can affect motion. | Investigate the forces between two or more magnets to identify patterns. | Collision  Magnets  Attract  Repel | 3.2.3.B1  3.2.3.B2  3.2.4.B1  3.2.4.B2  3.2.3.B6  3.2.4.B4 | S4.C.3.1 |
| **3-4** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | When objects touch or collide, they push on one another and can change motion or shape. Magnets create a magnetic field that can exert an attracting or repelling force on other objects that can affect motion. | Investigate the push-and-pull forces between objects not in contact with one another. | Collision  Magnets  Attract  Repel | 3.2.3.B1  3.2.3.B2  3.2.4.B1  3.2.4.B2  3.2.3.B6  3.2.4.B4 | S4.C.3.1 |
| **3-4** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | When objects touch or collide, they push on one another and can change motion or shape. Magnets create a magnetic field that can exert an attracting or repelling force on other objects that can affect motion. | Design and refine solutions to a problem by using magnets to move objects not in contact with one another. | Collision  Magnets  Attract  Repel | 3.2.3.B1  3.2.3.B2  3.2.4.B1  3.2.4.B2  3.2.3.B6  3.2.4.B4 | S4.C.3.1 |
| **3-4** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Materials that allow electricity to flow are  conductors; those that do not are insulators. | Investigate and describe conductors and insulators. | Insulator  Conductor  Electricity | 3.2.3.B4  3.2.4.B4 |  |
| **3-4** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Electrical circuits require a complete loop through which an electrical current can pass. | Construct serial and parallel circuits and describe the path of electrons in the circuit. | Serial Circuit  Parallel Circuit  System | 3.2.3.B4  3.2.4.B4 |  |
| **3-4** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | An open circuit is an incomplete electric  pathway; a closed circuit is a complete pathway. | Construct open and closed circuits utilizing switches. | Open Circuit  Closed Circuit  Switch  System | 3.2.3.B4  3.2.4.B4 |  |
| **3-4** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | A core of iron or steel becomes an electromagnet when electricity flows through a coil of insulated wire surrounding it. | Construct an electromagnet and describe how one can make the electromagnet stronger or weaker. | Electromagnet  System | 3.2.6.B4  3.2.4.B6  3.2.5.B3 |  |
| **3-4** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | A system can appear to be unchanging when processes within the system are going on at opposite but equal rates (e.g., water behind a dam is at a constant height because water is flowing in at the same rate that water is flowing out). | Construct an explanation for why an object subjected to multiple pushes and pulls might stay in one place or move. | Systems | 3.2.4.B1 | S4.C.3.1 |
|  |  |  |  |  |  |  |  |
| **5-6** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Electromagnetic forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. | Plan and carry out investigations to illustrate the factors that affect the strength of electric and magnetic forces. | Electromagnetic Forces  Current | 3.4.7.C 3.6.7.C | S8.C.3.1 |
| **5-6** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Long-range gravitational interactions govern the evolution and maintenance of large-scale systems in space, such as galaxies or the solar system, and determine the patterns of motion within those structures. | Use a model or various representations to describe the relationship among gravitational force, the mass of the interacting objects, and the distance between them. | Gravitational Interaction | 3.2.6.B1 3.2.5.B1 3.2.7.B1 |  |
| **5-6** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Forces that act at a distance (gravitational, electric, and magnetic) can be explained by force fields that extend through space and can be mapped by their effect on a test object. | Plan and carry out investigations to demonstrate that some forces act at a distance through fields. | Gravitational Interactions  Electrical Interactions  Magnetic Interactions | 3.2.6.B1 3.2.5.B1 3.2.7.B1 |  |
| **5-6** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass (e.g., Earth and the sun). | Develop a simple model using given data that represents the relationship of gravitational interactions and the motion of objects in space. | Gravitational Forces  Mass | 3.2.6.B1 3.2.5.B1 3.2.7.B1 |  |
| **7-8** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | In order to share information about an object's direction of force and motion with other people, a frame of reference must also be shared. | Formulate questions arising from investigating how an observer’s frame of reference and the choice of units influence how the motion and position of an object can be described and communicated to others. | Frame of Reference  Position  Relative Motion | 3.4.7.C 3.6.7.C | S8.C.3.1  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. | Communicate observations and information graphically and mathematically to represent how an object’s relative position, velocity, and direction of motion are affected by forces acting on the object. | Net Force  Force  Position  Velocity  Acceleration | 3.2.6.B1 3.2.5.B1 3.2.7.B1 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. | Analyze and interpret data to determine the cause and effect relationship between the motion of an object and the sum of the forces acting upon it. | Net Force  Acceleration | 3.2.6.B1 3.2.5.B1 3.2.7.B1 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. | Use mathematical concepts and observations to describe the proportional relationship between the acceleration of an object and the force applied upon the object, and the inversely proportional relationship of acceleration to its mass. | Mass  Force  Acceleration | 3.2.6.B1 3.2.5.B1 3.2.7.B1 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Forces on an object can change its shape or orientation. | Plan and carry out investigations to identify the effect forces have on an object’s shape and orientation. | Force | 3.2.6.B1 3.2.5.B1 3.2.7.B1 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
|  |  |  |  |  |  |  |  |
| **9-12** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Newton’s second law accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light. | Plan and carry out investigations to show that the algebraic formulation of Newton’s second law of motion accurately predicts the relationship between the net force on macroscopic objects, their mass, and acceleration and the resulting change in motion. | Force  Mass  Acceleration | 3.2.10.B1 3.2.P.B1 |  |
| **9-12** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Newton’s second law accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light. | Communicate arguments to support claims that Newton’s laws of motion apply to macroscopic objects but not to objects at the subatomic scales or speeds close to the speed of light. No details of quantum physics or relativity are included. | Force  Mass  Acceleration | 3.2.10.B1 3.2.P.B1 3.2.10.B6 3.2.12.B6 |  |
| **9-12** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. | Construct arguments for which type of atomic and molecular representation best explains a given property of matter. | Electromagnetic Forces  Electric Fields | S11.C.3.1 3.4.10.C 3.6.10.C 3.2.12.B4 3.2.10.B1 3.2.12.B4 |  |
| **9-12** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. | Analyze and interpret data obtained from measuring the bulk properties of various substances to explain the relative strength of the interactions among particles in the substance. | Electromagnetic Force  Electric Field | 3.2.12.B4 |  |
| **9-12** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. | Use mathematical expressions to determine the relationship between the variables in Newton's Law of Gravitation and Coulomb's Law and use these to predict the electrostatic and gravitational forces between objects. | Universal Gravitation  Electrostatic Forces | 3.2.10.B1 3.2.10.B1 |  |
| **9-12** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. | Use models to demonstrate that electric forces at the atomic scale affect and determine the structure, properties (including contact forces), and transformations of matter. | Electric Field  Electric Force | 3.2.10.B4 |  |
| **9-12** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | Forces at a distance are explained by fields permeating space that can transfer energy through space. Magnets or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields. | Plan and carry out investigations to demonstrate the claim that magnets, electric currents, or changing electric fields cause magnetic fields and electric charges or changing magnetic fields cause electric fields. | Magnetic Field  Electric Field  Electric Current | 3.2.10.B4 3.2.12.B4 3.2.P.B4 |  |
| **9-12** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | The strong and weak nuclear interactions are important inside atomic nuclei—for example, they determine the patterns of which nuclear isotopes are stable and what kind of decays occur for unstable ones. | Obtain, evaluate, and communicate information to show that strong and weak nuclear interactions inside atomic nuclei determine which nuclear isotopes are stable, and that the pattern of decay of an unstable nucleus can often be predicted. | Fundamental Forces  Strong Nuclear Forces  Weak Nuclear Force  Stable Isotopes  Unstable Isotopes | 3.2.12.A2  3.2.12.A3 |  |
| **9-12** | Interactions between any two objects can cause changes in one or both between and within atoms. | How can one explain and predict interactions between objects within systems? | When a system has a great number of component pieces, one may not be able to predict much about its precise future. For such systems (e.g., with very many colliding molecules), one can often predict average but not detailed properties and behaviors (e.g., average temperature, motion, and rates of chemical change but not the trajectories or other changes of particular molecules). | Construct explanations using data from system models or simulations to support the claim that systems with many molecules have predictable behavior, but that the behavior of individual molecules is unpredictable. | System  Entropy  Statistical Modeling | 3.4.10.C 3.6.10.C 3.2.10.B6 | S11.C.3.1 |
|  |  |  |  |  |  |  |  |
| **PreK-2** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | The faster a given object is moving, the more energy it possesses. | Carry out investigations to provide evidence that energy is being transferred or conserved by objects. | Conserved  Transfer  Energy  Investigation | 3.2.4.B1  3.2.4.B2  3.2.4.B6 | S4.C.3.1.1  S4.C.3.1.2  S4.3.1.3  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | The amount and position of mass affect how an object rotates and/or balances. | Carry out investigations to provide evidence that energy is being transferred or conserved by objects. | Investigation  Energy  Balance  Conserved  Transfer  Mass  Rotate | 3.2.4.B1  3.2.4.B2  3.2.4.B6 | S4.C.3.1.1  S4.C.3.1.2  S4.3.1.3  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
|  |  |  |  |  |  |  |  |
| **3-4** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | The faster a given object is moving, the more energy it possesses. | Construct a simple explanation for the relationship between energy and motion. | Energy  Motion | 3.2.3.B2 | S4.C.2.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Energy can be moved from place to place by moving objects or through sound, light, or electric currents. | Carry out investigations to provide evidence that energy is transferred from place to place by sound, light, heat, electric currents, interacting magnets, and moving or colliding objects. | Energy  Sound  Light  Electric Current  Heat  Magnets  Collision | 3.2.4.B2 | S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Energy can be moved from place to place by moving objects or through sound, light, or electric currents. | Obtain and communicate information for how technology allows humans to concentrate, transport, and store energy for practical use. | Energy  Sound  Light  Electric Current | 3.2.3.B2 | S4.C.2.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Energy can be moved from place to place by moving objects or through sound, light, or electric currents. | Design and construct a device that converts energy from one form to another using given design criteria. | Energy  Sound  Light  Electric Current  Energy Conversion | 3.2.3.B2 | S4.C.2.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Energy can be moved from place to place by moving objects or through sound, light, or electric currents. | Design and test a solution to a problem that utilizes the transfer of electric energy in the solution using given design constraints. | Energy Transfer  Sound  Light  Electric Current | 3.2.3.B2 | S4.C.2.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Energy can be moved from place to place by moving objects or through sound, light, or electric currents. | Develop a model using examples to explain differences between renewable and non-renewable sources of energy. | Renewable Energy  Non-Renewable Energy  Sound  Light  Electric Current | 3.2.3.B2 | S4.C.2.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Energy can be moved from place to place by moving objects or through sound, light, or electric currents. | Carry out investigations to provide evidence that energy is transferred from place to place by sound, light, heat, electric currents, interacting magnets, and moving or colliding objects. | Sound  Light  Electric Current  Magnet  Energy Transfer Collision | 3.2.4.B2 | S4.C.3.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Energy can be moved from place to place by moving objects or through sound, light, or electric currents. | Construct simple explanations for how forces on an object cause the object to change its energy. | Sound  Light  Electric Current | 3.2.3.B2 | S4.C.2.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Energy is present whenever there are moving objects, sound, light, or heat. | Construct a simple explanation for the relationship between energy and motion. | Energy  Light  Sound | 3.4.4.B  3.4.4.C 3.2.3.B2 3.2.4.B6 | S4.C.2.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air. As a result, the air gets heated and sound is produced. | Construct a simple explanation for the relationship between energy and motion. | Energy  Light  Sound  Collision  Heat | 3.4.4.B  3.4.4.C 3.2.3.B2 3.2.4.B6 | S4.C.2.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | When objects collide, the contact forces transfer energy so as to change the motion of each object. | Construct a simple explanation for the relationship between energy and motion. | Force  Energy  Motion  Collision  Energy Transfer | 3.2.4.B2 | S4.C.3.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Magnets can exert forces on other magnets or on magnetizable materials, causing energy transfer between them (e.g., leading to changes in motion) even when the objects are not touching. | Demonstrate the energy transfer between two objects using a magnet and another object. | Magnet  Force  Energy Transfer | 3.2.4.B2 | S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | The expression “produce energy” typically refers to the conversion of stored energy into a desired form for practical use. It is important to be able to concentrate energy so that it is available for use where and when it is needed (e.g., batteries). | Obtain and communicate information explaining how technology allows humans to concentrate, transport, and store energy for practical use. | Energy Production  Stored Energy  Conversion  Battery | 3.2.12.B5 | S4.C.2.1.1  S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
|  |  |  |  |  |  |  |  |
| **5-6** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Energy is transferred from hotter regions or objects and into colder ones by the processes of conduction, convection, and radiation. | Use and/or construct models to communicate the means by which thermal energy is transferred during conduction, convection, and radiation. | Thermal Energy  Energy Transfer  Conduction  Convection  Radiation | 3.4.7.B 4.2.7.B 3.2.7.B3 3.2.6.B3 3.2.6.B6 | S8.C.2.1  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **5-6** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Whenever a transformation of energy occurs, some of the energy in the system appears as thermal energy. | Compare, evaluate, and design a device that maximizes or minimizes thermal energy transfer, and defend the selection of materials chosen to construct the device. | Thermal Energy  Energy Transfer | 3.2.5.B3 3.2.7.B6 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **5-6** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Whenever a transformation of energy occurs, some of the energy in the system appears as thermal energy. | Design and evaluate solutions that minimize and/or maximize friction and energy transfer in everyday machines. | Thermal Energy  Energy Transfer  Friction  Machine | 3.2.5.B3 3.2.7.B6 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
|  |  |  |  |  |  |  |  |
| **7-8** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | The term “heat” as used in everyday language refers both to thermal motion (the motion of atoms or molecules within a substance) and electromagnetic radiation (particularly infrared and light). Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. | Use a simulation or mechanical model to determine the effect on the temperature and motion of atoms and molecules of different substances when thermal energy is added or removed from the substance. | Heat  Temperature  Atoms  Molecules  Substance  Electromagnetic Radiation | 3.4.7.B, 4.2.7.B 3.2.5.B3 3.2.6.B3 3.2.8.B3 | S8.C.2.1  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | The term “heat” as used in everyday language refers both to thermal motion (the motion of atoms or molecules within a substance) and electromagnetic radiation (particularly infrared and light). Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. | Construct an argument that explains the effect of adding or removing thermal energy to a pure substance in different phases and during a phase change in terms of atomic and molecular motion. | Heat  Temperature  Atoms  Molecules  Substance  Electromagnetic Radiation  Phase Change | 3.4.7.B  4.2.7.B 3.2.5.B3 3.2.6.B3 3.2.8.B3 | S8.C.2.1  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Motion energy is called kinetic energy; it is proportional to the mass of the moving object  and grows with the square of its speed. | Construct an explanation of the proportional relationship pattern between the kinetic energy of an object and its mass and speed. | Kinetic Energy  Mass  Speed | 3.2.6.B2 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | A system of objects may contain stored (potential) energy, depending on their relative positions. | Use representations of potential energy to construct an explanation of how much energy an object has when it’s in different positions in an electrical, gravitational, and magnetic field. | System  Potential Energy  Electrical Field  Gravitational Field  Magnetic Field | 3.2.6.B2 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Potential energy is decreased in some chemical reactions and increased in others. | Plan and carry out investigations to show that in some chemical reactions energy is released or absorbed. | Potential Energy  Chemical Reactions  Exothermic  Endothermic | 3.2.6.B2 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Potential energy is decreased in some chemical reactions and increased in others. | Use and/or construct models to communicate the means by which thermal energy is transferred during conduction, convection, and radiation. | Potential Energy  Chemical Reactions  Thermal Energy  Conduction  Convection  Radiation | 3.2.7.B3 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Temperature is a measure of the average kinetic energy of particles of matter. | Use and/or construct models to communicate the means by which thermal energy is transferred during conduction, convection, and radiation. | Potential Energy  Chemical Reactions  Thermal Energy  Conduction  Convection  Radiation  Temperature  Kinetic Energy | 3.2.7.B3 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. | Collect data and generate evidence to examine the relationship between the change in the temperature of a sample and the nature of the matter, the size of the sample, and the environment. | Temperature  System  Total Energy  Potential Energy  Kinetic Energy | 3.2.8.B3 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | The amount of energy transfer needed to change the temperature of a sample depends on the nature of the matter, the size of the sample, and the environment. | Collect data and generate evidence to examine the relationship between the change in the temperature of a sample and the nature of the matter, the size of the sample, and the environment. | Specific Heat  Energy Transfer | 3.4.7.B 4.2.7.B 3.2.7.B3 3.2.6.B3 3.2.6.B6 | S8.C.2.1  S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | A stable system is one in which any small change results in forces that return the system to its prior state. | Develop or modify models to demonstrate that systems can withstand small changes, relying on feedback mechanisms to maintain stability. | Stable System  Feedback | S8.C.3.1 3.4.7.C 3.6.7.C | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Many systems rely on feedback mechanisms to maintain stability function within a limited range of conditions. With no energy inputs, a system starting out in an unstable state will continue to change until it reaches a stable configuration (e.g., sand in an hourglass). | Develop or modify models to demonstrate that systems can withstand small changes, relying on feedback mechanisms to maintain stability. | Stable System  Feedback | 3.4.5.C2 3.4.8.A2 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
|  |  |  |  |  |  |  |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Chemical energy generally is used to mean the energy that can be released or stored in chemical processes, and electrical energy may mean energy stored in a battery or energy transmitted by electric currents. | Construct mathematical models to explain how energy changes in chemical reactions are caused by changes in binding energy as the reactants form products and in which changes in the kinetic energy of the system can be detected as change in temperature. | Chemical Energy  Electrical Energy  Battery  Chemical Reaction  Binding Energy  Reactants  products  temperature | 3.4.10.B | S11.C.2.1 |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. There is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. | Construct and defend models and mathematical representations that show that over time the total energy within an isolated system is constant, including the motion and interactions of matter and radiation within the system. | Energy  Isolated System  Conservation of Energy  Energy Transfer | 3.2.10.B2 3.2.12.B2 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | A system’s total energy is conserved with energy that is continually transferred from one object to another and between its various possible forms. | Construct models to show that energy is transformed and transferred within and between living organisms. | Energy  System  Conservation of Energy  Energy Transfer | 3.2.10.B2 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Energy transfer relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). | Construct models to represent and explain that all forms of energy can be viewed as either the movement of particles or energy stored in fields. | Energy Transfer | 3.2.10.B5 3.2.P.B5 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Energy transfer relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles). | Construct representations that show that some forms of energy may be best understood at the molecular or atomic scale. | Energy Transfer | 3.2.10.B5 3.2.P.B5 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. | Design, build, and evaluate devices that convert one form of energy into another form of energy. | Mechanical Energy  Potential Energy  Kinetic Energy | 3.2.10.B2 3.2.12.B2 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Mathematical expressions, which quantify kinetic energy and potential energy, allow the concept of conservation of energy to be used to predict and describe system behavior. | Construct and defend models and mathematical representations that show that over time the total energy within an isolated system is constant, including the motion and interactions of matter and radiation within the system. | Conservation of Energy  Kinetic Energy  Potential Energy  Isolated System | 3.4.10.B 3.2.10.B2 3.2.12.B2 3.2.P.B2 | S11.C.2.1 |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. | Identify problems and suggest design solutions to optimize the energy transfer into and out of a system. | Conservation of Energy  System | 3.2.10.B2 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Mathematical expressions, which quantify kinetic energy and potential energy, allow the concept of conservation of energy to be used to predict and describe system behavior. | Construct models to show that energy is transformed and transferred within a system. | Conservation of Energy  Energy transfer | 3.2.10.B2 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). | Analyze data to support claims that closed systems move toward more uniform energy distribution. | Unstable System  Stable System | 3.2.10.B2 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). Any object or system that can degrade with no added energy is unstable. | Design a solution to minimize or slow a system’s inclination to degrade to identify the effects on the flow of the energy in the system. | Unstable System  Stable System | 3.2.12.B2 3.2.C.B2 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. | Construct models to show that energy is transformed and transferred within and between living organisms. | Conservation of Energy | 3.2.12.B2 3.2.C.B2 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). | Construct models to show that energy is transformed and transferred within and between living organisms. | Conservation of Energy  Unstable System  Stable System | 3.2.12.B2 3.2.C.B2 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. | Design, build, and evaluate devices that convert one form of energy into another form of energy. | Conservation of Energy | 3.2.10.B2 3.2.12.B 3.2.P.B2 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Force fields (gravitational, electric, and magnetic) contain energy and can transmit energy across space from one object to another. | Plan and carry out investigations in which a force field is mapped to provide evidence that forces can transmit energy across a distance. | Gravitational Fields  Electric Fields  Magnetic Fields | 3.4.10.B 3.2.12.B4 3.2.10.B4 3.2.10.B5 3.2.P.B5 | S11.C.2.1 |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | When two objects interacting through a force field change relative position, the energy stored in the force field is changed. | Develop arguments to support the claim that when objects interact at a distance, the energy stored in the field changes as the objects change relative position. | Gravitational Fields  Electric Fields  Magnetic Fields | 3.2.12.B4 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | When two objects interacting through a force field move relative to each other,, the energy stored in the force field is changed. | Evaluate natural and designed systems where there is an exchange of energy between objects and fields and characterize how the energy is exchanged. | Gravitational Fields  Electric Fields  Magnetic Fields | 3.2.12.B4 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | The production of electricity using different fuels have associated economic, social, and environmental costs and benefits, both short and long term, depending on the type of fuel used. | Ask questions and make claims about the relative merits of nuclear processes compared to other types of energy production. | Renewable  Resource  Non-Renewable Resource | S11.C.2.2 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Although energy cannot be destroyed, it can be converted to less useful forms. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. | Identify problems and suggest design solutions to optimize the energy transfer into and out of a system. | Conservation of Energy  Machine  System | S11.C.2.2 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | In any system, total momentum is always conserved. If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. | Use algebraic equations to predict the velocities of objects after an interaction when the masses and velocities of objects before the interaction are known. | System  Conservation of Momentum | S11.C.3.1 3.4.10.C 3.6.10.C 3.2.10.B1 3.2.12.B2 3.2.10.B6 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. In any system, total momentum is always conserved. | Generate and analyze data to support the claim that the total momentum of a closed system of objects before an interaction is the same as the total momentum of the system of objects after an interaction. | Momentum  Reference Frame  Conservation of Momentum  Elastic collision  Inelastic Collision | 3.2.10.B1 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. | Construct a scientific argument supporting the claim that the predictability of changes within systems can be understood by defining the forces and changes in momentum both inside and outside the system. | System  Conservation of Momentum  Elastic collision  Inelastic Collisions | 3.2.10.B1 |  |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Systems often change in predictable ways; understanding the forces that drive the transformations and cycles within a system, as well as the forces imposed on the system from outside, helps predict its behavior under a variety of conditions. | Design and evaluate devices that minimize the force on a macroscopic object during a collision. | System  Elastic collision  Inelastic Collision | 3.4.10.C, 3.6.10.C 3.2.10.B6 | S11.C.3.1 |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | Systems often change in predictable ways; understanding the forces that drive the transformations and cycles within a system, as well as the forces imposed on the system from outside, helps predict its behavior under a variety of conditions. | Construct a scientific argument supporting the claim that the predictability of changes within systems can be understood by defining the forces and changes in momentum both inside and outside the system. | Systems | 3.4.10.C 3.6.10.C  3.2.10.B6 | S11.C.3.1 |
| **9-12** | Interactions of objects or systems of objects can be predicted and explained using the concept of energy transfer and conservation. | How is energy transferred and conserved? | The faster a given object is moving, the more energy it possesses. | Construct a simple explanation for the relationship between energy and motion. | Kinetic Energy | 3.2.3.B2 | S4.C.2.1 |
|  |  |  |  |  |  |  |  |
| **PreK-2** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | An object can be seen when light reflected from its surface enters the eyes. | Investigate and explain that for an object to be seen, light must be reflected off the object and enter the eye. | Wave  Energy  Light  Reflection | 3.2.3.B5 3.2.4.B5 3.2.1.B5 | S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | The color people see depends on the color of the available light sources as well as the properties of the surface. | Investigate and explain that for an object to be seen, light must be reflected off the object and enter the eye. | Wave  Energy  Light  Reflection | 3.2.3.B5 3.2.4.B5 3.2.1.B5 | S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Sound can make matter vibrate and vibrating matter can make sound | Conduct and investigation to provide evidence that vibrating matter can make sound and the sound can cause matter to vibrate. | Sound  Vibrate  Matter | 3.2.4.B5 | S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **PreK-2** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Very hot objects give off light | Record and communicate observations that some very hot objects give off their own light. | Light  Temperature | 3.2.4.B3 | S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
|  |  |  |  |  |  |  |  |
| **3-4** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Waves are regular patterns of motion, and can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; it does not move horizontally. | Identify the patterns of waves by observing their motion in water. | Waves  Energy  Information  Motion | 3.2.4.B5  3.2.4.B6 | S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Waves are regular patterns of motion, and can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; it does not move horizontally. | Provide evidence that waves transfer energy to objects as a wave passes. | Waves  Energy Transfer  Information  Motion | 3.2.4.B6 | S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Waves of the same type can differ in amplitude(height of the wave) and wavelength (spacing between wave peaks). | Use a model to describe the amplitude and wavelength of waves. | Waves  Amplitude  Wavelength | 3.2.4.B5  3.2.4.B6 | S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; it does not move in the direction of the wave—observe, for example, a bobbing cork or seabird—except when the water meets the beach. | Plan data collection methods and make observations to provide evidence that waves transfer energy to objects | Waves  Energy Transfer | 3.2.4.B5  3.2.4.B6 | S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Earthquakes cause seismic waves, which are waves of motion in the Earth’s crust. | Describe how similar seismic waves are to other types of waves. | Seismic Waves  Earthquake | 3.2.4.B5  3.2.4.B6 | S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | An object can be seen when light reflected from its surface enters the eyes. | Investigate and provide evidence that the color people see depends on the color of the available light sources as well as the properties of the surface of the object reflecting the light. | Reflection  Refraction | 3.2.3.B5 3.2.4.B5 | S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | The color people see depends on the color of the available light sources as well as the properties of the surface. | Investigate and provide evidence that the color people see depends on the color of the available light sources as well as the properties of the surface of the object reflecting the light. | Color  Reflection | 3.2.3.B5 3.2.4.B5 | S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
| **3-4** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Digitized information (e.g., the pixels of a picture) can be stored for future recovery or transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. | Obtain and communicate information about modern devices that are used to transmit and receive digital information. | Digitized Information  Pixels  Encode  Decode  Transmit | 3.4.4.B1 3.4.4..B3 | S4.A.1.1  S4.1.3.1  S4.A.2.1.4 |
|  |  |  |  |  |  |  |  |
| **5-6** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. | Use a drawing or physical representation of simple wave properties to explain brightness (amplitude) and color (frequency / wavelength). | Wave  Wave Length  Amplitude  Frequency  Brightness  Color | 3.2.7.B5 |  |
| **5-6** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | A sound wave needs a medium through which it is transmitted. | Plan and carry out investigations of sound traveling through various types of mediums and lack of medium to determine whether a medium is necessary for the transfer of sound waves. | Medium  Sound Wave  Vacuum | 3.2.5.B5 |  |
| **5-6** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object’s material and the frequency (color) of the light. | Construct explanations of how waves are reflected, absorbed or transmitted through an object, considering the material the object is made from and the frequency of the wave. | Light  Reflection  Absorption  Transmission  Frequency  Color | 3.2.7.B5 |  |
| **5-6** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | The path that light travels can be traced as straight lines, except at surfaces between different transparent materials where the light path bends. | Use empirical evidence to support the claim that light travels in straight lines except at surfaces between different transparent materials. | Light  Transparent | 3.2.3.B5  3.2.4.B5 |  |
| **5-6** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Appropriately designed technologies (e.g., radio, television, cell phones, wired and wireless computer networks) make it possible to detect and interpret many types of signals that cannot be sensed directly. | Apply scientific knowledge to explain the application of waves in common communication designs. | Signals | 3.4.6.E4 |  |
|  |  |  |  |  |  |  |  |
| **7-8** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. | Construct explanations of how waves are reflected, absorbed or transmitted through an object, considering the material the object is made from and the frequency of the wave. | Seismic Waves  Reflection  Absorption  Transmission | 3.2.7.B5  3.4.6.E4 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | A wave model of light is useful for explaining brightness (amplitude), color (frequency, wavelength), and the frequency-dependent bending of light at a surface between media. | Use a drawing or physical representation of the wave model of light to explain the change in direction of the wave due to a change in its medium. | Wave Model  Brightness  Amplitude  Color  Frequency  Wavelength  Refraction  Medium | 3.2.4.B5 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
| **7-8** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Many modern communication devices use  digitized signals (sent as wave pulses) as a more reliable way to encode and transmit information. | Apply scientific knowledge to explain the application of waves in common communication designs. | Encode  Transmit  Decode  Wave Pulse | 3.4.7.B3 3.4.6.B4 | S8.A.1.3  S8.A.2.2  S8.A.2.1 |
|  |  |  |  |  |  |  |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | The speed of a wave in any medium is the product of the wave's frequency and wavelength. | Plan and carry out investigations to determine the mathematical relationships among wave speed, frequency, and wavelength, and how they are affected by the medium through which the wave travels. | Wave Speed  Medium  Frequency  Wavelength | 3.4.10.B 3.2.P.B5 | S11.C.2.1 |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | The relationship between the wavelength and frequency of a wave depends on the speed of a wave as it passes through a medium. | Plan and carry out investigations to determine the mathematical relationships among wave speed, frequency, and wavelength, and how they are affected by the medium through which the wave travels. | Wave speed  Medium  Frequency  Wavelength | 3.4.10.B 3.2.P.B5 | S11.C.2.1 |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | The speed of a wave in any medium is the product of the wave's frequency and wavelength. | Carry out an investigation to describe a boundary between two media that affects the reflection, refraction, and transmission of waves crossing the boundary. | Wave Speed  Medium  Frequency  Wavelength | 3.2.P.B5 |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | The relationship between the wavelength and frequency of a wave depends on the speed of a wave as it passes through a medium. | Carry out an investigation to describe a boundary between two media that affects the reflection, refraction, and transmission of waves crossing the boundary. | Wave Speed  Medium  Frequency  Wavelength | 3.2.P.B5 |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. | Investigate the patterns created when waves of different frequencies combine, and explain how these patterns are used to encode and transmit information. | Frequency  Superposition | 3.2.P.B5 |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Objects have natural frequencies and when they are forced to vibrate at that frequency, they resonate with large vibrations. | Use drawings, physical replicas or computer simulation models to explain that resonance occurs when waves add up in phase in a structure, and that structures have a unique frequency at which resonance occurs. | Resonance  Natural Frequency  Phase | 3.2.P.B5 |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Information can be digitized and efficiently stored and transmitted as a series of numbers. | Obtain, evaluate, and communicate scientific literature about the differences and similarities between analog and digital representations of information to describe the relative advantages and disadvantages. | Digital  Analog | 3.2.12.B5 |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Electromagnetic radiation is created by vibrating charges that produce both electric and magnetic fields that propagate away from the charges. | Use arguments to support the claim that electromagnetic radiation can be described using both a wave model and a particle model, and determine which model provides a better explanation of phenomena. | Electromagnetic Radiation  Photon  Electric Field  Magnetic Field  Wave Model  Particle Model | 3.4.10.B 3.2.10.B5 | S11.C.2.1 |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Electromagnetic waves can also be characterized as photons that travel at the speed of light. | Use arguments to support the claim that electromagnetic radiation can be described using both a wave model and a particle model, and determine which model provides a better explanation of phenomena. | Electromagnetic Radiation  Photon  Electric Field  Magnetic Field  Wave Model  Particle Model | 3.4.10.B 3.2.10.B5 | S11.C.2.1 |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Electromagnetic radiation travels through a vacuum at the speed of light and slows down as it travels through a medium. The speed through any given medium is determined by the properties of the medium and the wavelength of the electromagnetic radiation. | Obtain, evaluate, and communicate scientific literature to show that all electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. | Electromagnetic Radiation  Medium  Speed of Light  Vacuum | 3.2.10.B5 3.2.P.B5 |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Any interaction between electromagnetic radiation and matter depends on the wavelength of the electromagnetic radiation and the size of the interacting matter. | Obtain, evaluate, and communicate scientific literature about the effects different wavelengths of electromagnetic radiation have on matter when the matter absorbs it. | Electromagnetic Radiation  Wavelength | 3.2.10.B5 3.2.P.B5 |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. | Construct an explanation of how photovoltaic materials work using the particle model of light, and describe their application in everyday devices. | Photovoltaic Materials  Particle Model | 3.2.P.B5  3.2.12.B5 |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | Because atoms of each element emit and absorb characteristic frequencies of light, an analysis of that light can be used to identify various atoms. | Analyze and interpret data of both atomic emission and absorption spectra of different samples to make claims about the presence of certain elements in the sample. | Emission Spectra  Absorption Spectra | 3.2.12.A2 |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | The interaction of electromagnetic radiation with matter depends on the size of the matter and the wavelength of the radiation that interacts with it. | Construct explanations for why the wavelength of an electromagnetic wave determines its use for certain applications. | Electromagnetic  Radiation  Wavelength | 3.2.12.B5 |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | The interaction of electromagnetic radiation with matter depends on the size of the matter and the wavelength of the radiation that interacts with it. | Construct explanations for why the wavelength of an electromagnetic wave determines its use for certain applications. | Electromagnetic  Radiation    Wavelength | 3.2.12.B5 |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | There are several types of technology that utilize the properties of waves to interact with matter that communicate information, image objects, and conduct scientific research. | Construct an explanation of how photovoltaic materials work using the particle model of light, and describe their application in everyday devices. | Photovoltaic Material  Particle Model | 3.2.12.B5 3.2.P.B5 |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | There are several types of technology that utilize the properties of waves to interact with matter that communicate information, image objects, and conduct scientific research. | Obtain, evaluate, and communicate scientific literature about the differences and similarities between analog and digital representations of information to describe the relative advantages and disadvantages. | Digital  Analog | 3.2.12.B5 3.2.P.B5 |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | There are several types of technology that utilize the properties of waves to interact with matter that communicate information, image objects, and conduct scientific research. | Construct explanations for why the wavelength/frequency of an electromagnetic wave determines its use for certain applications. | Electromagnetic Wave  Wave Length  Frequency | 3.2.12.B5 3.2.P.B5 |  |
| **9-12** | Waves are a repeating pattern of motion that transfers energy from place to place without overall displacement of matter. | How are waves used to transfer energy and information? | When electromagnetic radiation is absorbed by matter, the wavelength of the electromagnetic radiation determines how it is absorbed. Longer wavelengths are absorbed as thermal energy while waves with short wavelengths can ionize atoms and cause damage to cells. | Construct explanations for why the wavelength of an electromagnetic wave determines its interaction with matter. | Electromagnetic Radiation  Thermal Energy  Ionizing Radiation  Non-Ionizing  Radiation | 3.2.P.B5 |  |